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(54) Tunable multiple fiber optical connector

(57) The present invention relates to a connector (100) for receiving and connecting multiple optical fiber ends (22). In particular, the present invention relates to a tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends (22) to a second plurality of optical fiber ends comprising: a first connector housing (30A) comprising at least a first key element (36), the connector housing (30A) for retaining each of the first plurality of optical fiber ends (22), a core (32) of each of the first plurality of optical fiber ends (22) oriented with respect to the same first key element (36) in a predetermined fashion in a plane perpendicular to the longitudinal axis of the fiber; and, a coupling mechanism for coupling the first connector housing (30A) to another connector housing (30B).

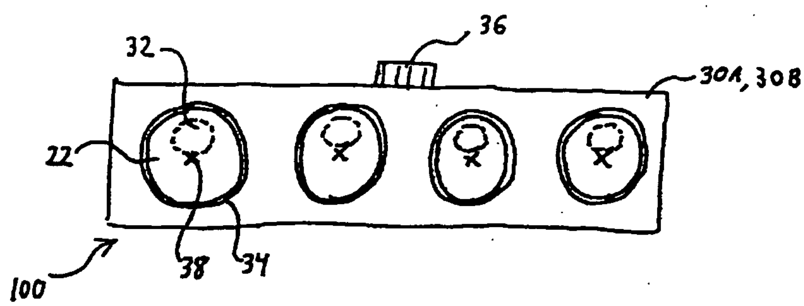

Fig. 5

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Description

[0001] A tuned multiple fiber optical connector and a method for tuning same is disclosed. A first connector housing retains each of a first plurality of optical fiber ends in a predetermined location. The first connector housing has a first key element. A core of each of the first plurality of optical fiber ends is oriented in a predetermined fashion with respect to the first key element. A second connector housing retains each of a second plurality of optical fiber ends in a predetermined location. The second connector housing comprises a second key element. A core of each of the second plurality of optical fiber ends is oriented in a predetermined fashion with respect to the second key element. The first and the second connector housings are coupled such that the key elements are disposed in a predetermined relation one to the other. Therefore, the core of each of the first plurality of optical fiber ends is substantially in alignment with the core of a corresponding optical fiber end of the second plurality of optical fiber ends.

[0002] The present invention relates to a connector for receiving and connecting multiple optical fiber ends. In particular, the present invention relates to a tunable multiple optical fiber connector for tuning the core position of each fiber in the connector to optimize coupling efficiency.

[0003] In fiber based optical systems, signals propagate within optical fibers. When optically coupling two components, a fiber is coupled at a first end to a first component and at a second end to a second component. Often in an optical system, a plurality of fibers is routed within the system. When a large number of fibers are used, designs often incorporate cables comprising a number of fibers and having a single connector at each end of the cable. The single multi-fiber connector is provided with bores for accepting optical fibers. Into each bore, a fiber is inserted and held in place. Unfortunately, the bores are not always precisely located and, in order to insert a fiber, the bores must be larger in diameter than the outside diameter of the fibers in order to accommodate the fibers.

[0004] Small irregularities in ferrule and fiber manufacture can result in significant signal loss, particularly in coupling single mode fibers. A standard ferrule has an internal diameter closely matching a fiber diameter. However, a ferrule having for example an internal diameter of 128 μm provided with a fiber having a diameter of 127 μm may be placed up to 0.5 μm from the concentric axis, equaling a total possible eccentricity of the optical fiber of 1 pm. In addition, the bore of the ferrule in manufacture may not be concentrically placed. Tuning is thus necessary to optimize the position of the fiber ends within a connector and thereby adjust the coupling efficiency. For example, a simple tuning apparatus allows for insertion of a connector in any of a plurality of orientations. Once inserted, the connector is fixed in its orientation and, therefore, the coupling efficiency remains substantially constant and is improved when coupling is between two ends having similar orientations.

[0005] Unfortunately, when using cables comprising multiple fibers, each fiber coupling may result in significant loss. Tuning of fibers by moving the two connector ends does not result in each fiber pair being independently tuneable. The relative placement of the connector ends cannot be reoriented because the fiber connections would change. When different fibers within a cable have alignment errors as is commonly noted, it is near impossible to find two connectors that couple efficiently for all fiber pairs. For example, when correct alignment is sufficiently approximated by aligning the connectors in one of four orientations, there is a one in four chance of a good coupling. Through tuning of a single fiber connector, the coupling is easily altered to achieve a most efficient coupling from the four available orientations. When two fibers are incorporated into a cable, there are 16 possible orientations and since tuning is not available, only one in 16 connectors provides good coupling with an existing connector. When a cable having 32 fibers is used, the chance of finding two that mate with reasonable coupling efficiency is very small.

[0006] For more efficient installation of multi fiber or ribbon fibers the coupling of multiple fiber ends at a single multi-fiber-connector pair, heretofore, has not been satisfactory. United States patent No. 5,671,311 to Stillie et al. discloses a method of aligning a number of receiving ferrules within a less precise housing by providing aligning pins for locating the ferrule bores in the housing. Once the ferrules are positioned the fibers are then inserted. This is a rather imprecise method, which does not provide an opportunity to correct transmission problems once the fibers and light sources are in place. Also, since the fiber is inserted after the tuning is performed, slack between the ferule and the fiber can be a significant problem.

[0007] Alternative multiple fiber connectors are disclosed in United States patent No. 5,430,819 to Sizer II et al. A first connector manufactured by AT&T under the trademark MACII, secures a plurality of exposed fiber ends between a pair of silicon wafers having a groove precision etched to locate each fiber end. A second connector in accordance with the invention of Sizer II et al. provides a pair of substrate plates having fiber-sized holes etched through the substrate for locating each fiber end. Both of these methods require absolutely precise manufacturing at considerable cost, since no tuning adjustment of individual fibers is possible.

[0008] Tuning of single optical fiber connectors is known. For example, it is known to provide a keying mechanism on an optical fiber connector to prevent rotation of the optical fiber cable once a desired coupling position has been determined, as described in United States patent No. 5,096,276 to Gerace et al. The key element may be an asymmetric shape or a pin or the like in a push-pull plug type connector.

[0009] Two fiber ends joined in a connector may each be supported in a ferrule or similar housing. Most commonly a cylindrical ferrule with a central bore substantially the diameter of the exposed fiber is used to support the fiber end within the connector. As recognized in United States patent No. 4738,508 to Palmquist, and also in United States patent No. 5390,269 to Palacek et al., tuning of the ferrules within the connector is also needed to achieve high performance connection with low insertion loss.

[0010] Palacek and Palmquist propose providing multiple rotatable orientations of a fiber and ferrule within the connector by placing the ferrule within a housing or collar having facets or knurls for mating with a receiving housing.

[0011] It is an object of the invention to provide a connector for receiving and connecting multiple optical fiber ends, in which each optical fiber core is oriented in a predetermined fashion with respect to a key element of a connector housing.

[0012] It is further an object of the invention to provide a connector for receiving and connecting multiple optical fiber ends, in which each optical fiber core can be tuned individually.

[0013] According to the present invention there is provided a tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising:

a first connector housing comprising a first key element, the first connector housing for retaining each of the first plurality of optical fiber ends in a predetermined location, a core of each of the first plurality of optical fiber ends oriented in a predetermined fashion with respect to the first key element;

a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber ends in a predetermined location and a core of each of the second plurality of optical fiber ends oriented in a predetermined fashion with respect to the second key element; and,

a coupling mechanism for coupling the first and the second connector housings such that when the key elements are disposed in a predetermined relation one to the other, the core of each of the first plurality of optical fiber ends is substantially in alignment with the core of a corresponding optical fiber end of the second plurality of optical fiber ends.

[0014] In a preferred embodiment according to the invention there is further provided a tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising:

a first plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule such that a core of the optical fiber end is oriented in a predetermined fashion with respect to a key element of the ferrule;

a second plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule such that a core of the optical fiber end is oriented in a predetermined fashion with respect to a key element of the ferrule;

a first connector housing comprising a first key element, the first connector housing for retaining each of the first plurality of optical fiber ends in a predetermined location such that the key elements of the ferrules are disposed in a predetermined relation to the first key element of the connector housing;

a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber ends in a predetermined location such that the key elements of the ferrules are disposed in a predetermined relation to the second key element of the connector housing; and,

a coupling mechanism for coupling the first and the second connector housings such that when the first and the second key elements are disposed in a predetermined relation one to the other, the core of each of the first plurality of optical fiber ends is substantially in alignment with the core of a corresponding optical fiber end of the second plurality of optical fiber ends.

[0015] According to the invention there is further provided a tunable multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising:

a first plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule;

a second plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule;

a first connector housing comprising a first key element, the first connector housing for retaining each of the first plurality of optical fiber ends in a predetermined location such that each ferrule is retained in a bore within the first connector housing in one of a plurality of orientations and prevented from rotating by engaging means;

a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber

ends in a predetermined location such that each ferrule is retained in a bore within the second connector housing in one of a plurality of orientations and prevented from rotating by engaging means; and,

a coupling mechanism for coupling the first and the second connector housings such that when the key elements are disposed in a predetermined relation one to the other, the core of each of the first plurality of optical fiber ends is in a predetermined orientation with respect to the core of a corresponding optical fiber end of the second plurality of optical fiber ends.

[0016] According to the present invention there is provided a method for tuning a multiple fiber optic connector for connecting a plurality of optical fiber ends comprising the steps of:

iteratively,

determining a core orientation with respect to a reference point of each optical fiber end of the plurality of optical fiber ends;

when a core orientation is a predetermined orientation, affixing the optical fiber ends in a connector housing such that the core of each of the optical fiber ends is oriented in a predetermined fashion with respect to a key element of the connector housing; and,

when the core orientation is other than the predetermined orientation, altering the core orientation of at least one of the plurality of optical fiber ends.

[0017] In a preferred embodiment according to the present invention there is further provided a method for tuning a multiple fiber optic connector for connecting a plurality of optical fiber ends comprising the steps of:

determining a core orientation with respect to a reference point of each optical fiber end of the plurality of optical fiber ends;

when a core orientation is a predetermined orientation, affixing the optical fiber end in a ferrule such that the core of the optical fiber end is oriented in a predetermined fashion with respect to a key element of the ferrule;

when the core orientation is other than the predetermined orientation, altering the core orientation; and,

affixing the ferrules in a connector housing such that the key elements of the ferrules are disposed in a predetermined relation to a key element of the connector housing.

[0018] In another preferred embodiment according to the present invention there is provided a method for tuning a multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising the steps of:

affixing each of the first plurality and the second plurality of optical fiber ends in a ferrule;

mating a first connector housing with a second connector housing such that key elements are disposed in a predetermined relation one to the other indicating mating of the two connector housings in one and only one orientation;

placing each of the first plurality of optical fiber ends and the corresponding fiber of the second plurality of optical fiber ends into a first and second connector housing, respectively, such that cores of the first plurality of optical fiber ends and the corresponding core of the second plurality of optical fiber ends have a first orientation relative to each other;

simultaneously launching light through each of the first and second plurality of optical fibers;

adjusting the relative orientation of the cores of each fiber pair until a preferred coupling is obtained; and,

when a preferred coupling is obtained securing the orientation of the fiber cores with respect to the key elements by affixing the ferrules within the connector housings.

[0019] Exemplary embodiments of the invention will now be described in conjunction with the drawings, in which:

Figure 1A is a transverse sectional view of a prior art, single fiber connector prior to tuning;

Figure 1B is a transverse sectional view of the connector of Figure 1A subsequent to tuning;

Figure 2A is a transverse sectional view of a further prior art single fiber connector prior to tuning;

Figure 2B is a transverse sectional view of the connector of Figure 2A subsequent to tuning;

Figure 3 is an isometric view of a prior art MACII multiple optical fiber connector;

Figure 4 is an isometric view of a further prior art

multiple optical fiber connector;

Figure 5 is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention;

Figure 5A is an isometric view of the connector of Figure 5 comprising a color code as a key element;

Figure 5B is an isometric view of the connector of Figure 5 comprising a pin and a hole as a key element;

Figure 5C is an isometric view of the connector of Figure 5 comprising an asymmetric housing as a key element;

Figure 6A is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention indicating a fiber core orientation;

Figure 6B is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention indicating a fiber core orientation;

Figure 6C is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention indicating a fiber core orientation;

Figure 6D is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention indicating a fiber core orientation;

Figure 7A is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention wherein each optical fiber is retained in a separate bore;

Figure 7B is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention wherein all optical fibers are retained in one bore;

Figure 7C is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention wherein a housing comprises several bores, each bore retaining several optical fibers;

Figure 8A illustrates a tuned multiple optical connector in accordance with the present invention comprising male and female connector housings;

Figure 8B illustrates a tuned multiple optical connector in accordance with the present invention comprising two connector housings having a same shape mated together by a third intermediate housing;

Figure 8C illustrates a tuned multiple optical connector in accordance with the present invention comprising two connector housings having a same shape mated together;

Figure 8D illustrates a tuned multiple optical connector in accordance with the present invention comprising a first connector housing mated with two connector housings;

Figure 9A is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention, wherein optical fiber ends are supported by a ferrule and the ferrule has a flattened face for engaging with a side wall of a bore;

Figure 9B is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention, wherein optical fiber ends are supported by a ferrule and the ferrule has grooves for engaging with a pin mounted within a bore;

Figure 9C is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention, wherein optical fiber ends are supported by a ferrule and the ferrule has an octagonal collar for engaging with matching surfaces a bore;

Figure 9D is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention, wherein optical fiber ends are supported by a ferrule and the ferrule retains a plurality of optical fiber ends; and,

Figure 9E is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention, wherein optical fiber ends are supported by a ferrule and a plurality of ferrules are retained in a single bore.

[0020] Figures 1A and 1B show an optical fiber end **22** within a prior art single tunable connector. The ferrule **8** supporting the fiber end **22** is surrounded by an octagonal collar **20** having outer faces **21**. The connector includes a positioning channel **3** for engaging the faces **21** of the ferrule collar **20**. The center of the ferrule **8** is marked **23**. It can be seen in Figure 1A that the fiber end **22** is positioned eccentrically. The eight faces of the collar **20** provide eight rotational positions for placing the ferrule within the connector. A position is chosen for most efficiently coupling the fiber end to a connecting fiber end disposed within an associated mating connector element.

[0021] Figures 2A and 2B show an alternative embodiment of the single prior art connector. The outer collar **10** has twelve ridges and depressions about the ferrule **8**. As a result twelve positions within the connector are

possible, allowing greater flexibility to the fiber positioning.

[0022] In modern communication networks a large amount of data is transferred via fiber optic cables. Fiber optic cables usually comprise a large number of individual optical fibers arranged, for example, in a ribbon like structure. Using a single connector for each fiber in order to connect two fiber optic cables is not a practical solution. The cable has to be split into the individual fibers a sufficient distance from the end so as to be able to connect each fiber pair individually. Further, substantial space is required for the large amount of connectors. This creates a large amount of fibers that are no longer aligned, crossing each other in different orientations. In such a confusing situation it is very likely that the wrong fibers are connected to each other. Also, maintenance and reliability are reduced because of the tangle of fibers that results. Therefore, it is preferable to connect the ends of two fiber optic cables with a single coupling.

[0023] Figures 3 and 4 illustrate prior art multiple connectors in which exposed fiber ends **101** and **201** are aligned in precisely machined locating plates. In both embodiments provision is made to adjust horizontal or vertical positioning of all of the fiber ends together to couple with an aligned additional set of fiber ends. No tuning of individual fibers is possible. Consequently, manufacturing irregularities such as variability in fiber diameter, eccentricity of the fiber core or variability in the machining of the plate cannot be compensated resulting in significant signal loss with each fiber coupling.

[0024] Figure 5 illustrates a transverse section through a multiple optical connector **100** in accordance with the present invention. The multiple optical connector **100** comprises a first housing **30A** and a second housing **30B**. Each housing **30A**, **30B** comprises a plurality of bores **34** for retaining the first and the second plurality of optical fiber ends **22**, respectively. Each of a plurality of optical fiber ends **22** is retained in a bore **34** within the connector housings **30A**, **30B** such that an optical fiber core **32** is in a plane perpendicular to the longitudinal axis of the fiber above the center **38** of the bore **34** retaining the optical fiber end **22**. In such an arrangement, each fiber core **32** is oriented with respect to a key element **36**. The key elements **36** of the connector housings **30A**, **30B** are mating key elements for substantially limiting the coupling of the two connector housings **30A**, **30B** to a single orientation. When the connector housings **30A**, **30B** are coupled the key elements **36** are disposed in a predetermined relation one to the other. The core **32** of each optical fiber end **22** retained in the first connector housing **30A** is then substantially in alignment with the core **32** of a corresponding optical fiber end **22** retained in the second connector housing **30B**. Key elements **36** are for example as illustrated in figures 5B to 5C: a pin **70** to fit in a hole **71** or asymmetric connector housings **72A**, **72B**. Alternatively as shown in Fig. 5A, the key element is other than a mating element, for example a colored mark **68**.

[0025] Such a connector is manufactured by iteratively determining the core orientation of each optical fiber end **22** with respect to a reference point. When the core orientation is substantially the predetermined core orientation the optical fiber end **22** is affixed in the connector housing **30** such that the core **32** is oriented in a predetermined fashion with respect to the key element **36** of the connector housing **30**. For example, the optical fiber ends **22** are affixed in the connector housing **30** using an adhesive such as epoxy. When the core orientation is other than the predetermined orientation, the core orientation is altered.

[0026] Provision of fiber optic cables with tuned and standardised multiple optical connectors, for example the fiber cores of all connectors are oriented in a same fashion as illustrated in Fig. 5, allows a user to connect fiber optic cables easily without a significant signal loss.

[0027] Figures 6A to 6D illustrate numerous possibilities to arrange the core orientation of the optical fiber ends **22** according to the present invention. The illustration in figure 6A shows the cores **32** of the optical fiber ends **22** having different orientations -up, right and down-. Such an arrangement of the fiber cores necessitates two different connector housings **30A**, **30B** for coupling, one being a mirror image of the other. In the arrangement shown in figure 6B the cores **32** of all optical fiber ends **22** point to one direction. Two connector housings **30A**, **30B** having such an arrangement are mated by turning one connector housing upside down. Figure 6C shows the fiber cores **32** retained in the left half of the connector housings **30A**, **30B** pointing to the left whereas the fiber cores **32** retained in the right half of the connector housings **30A**, **30B** are pointing to the right. Two such connector housings **30A**, **30B** are coupled either upside pointing to upside or one connector housing turned upside down relative to the other. The arrangements shown in figures 5 and 6A to 6C are useful for different embodiments of ribbon connectors. Figure 6D shows an arrangement of optical fibers **22** in a circular fashion, their cores **32** pointing from the center **33** of the circle outward. Such a connector allows coupling of two connector housings **31A**, **31B** in as many positions as the number of optical fibers **22** retained in the connector housings **31A**, **31B** by turning one housing about its center **33**. Of course, when a single connector orientation is desired, a key for substantially limiting connector coupling orientation is included within the connector.

[0028] Figures 7A to 7C illustrate various arrangements of optical fiber ends **22** retained in a connector housing **30** according to the present invention. In figure 7A each of the optical fiber ends **22** is retained separately in a bore **34**. This embodiment is advantageous for manufacturing because each fiber end **22** is oriented and affixed separately. In the embodiment shown in figure 7B all optical fiber ends **22** are retained in one bore **34**. This arrangement of optical fibers requires the

smallest amount of space but is difficult to manufacture because all fibers ends **22** are affixed at a same time. Figure 7C shows an arrangement of the optical fiber ends 22 wherein the connector housing **30** comprises several bores **34** with each bore **34** retaining several fiber ends **22**. Affixing the fibers is eased in this embodiment due to a reduced number of fibers retained in a single bore **34**.

[0029] Figures 8A to 8D illustrate different embodiments of a multiple fiber optic cable and connector assembly. Two push-pull connector housings **30A**, **30B** join fiber ends from a first optical cable **40** and a second optical cable **42**. The individual optical fibers are separated and stripped to expose the fiber ends **22** for placement in the connector housings **30A**, **30B**. A sufficient length of fiber is exposed to permit rotation of the fiber end through 180 degrees. Of course, a jacketed fiber is also rotatable and is considered exposed as that term is used herein. The loose fibers are provided with strain relief support elements and a covering (not shown). In the embodiment shown in figure 8A, two connector housings **30A**, **30B** of different shape to form a male and a female part are mated to couple the ends of the two fiber optic cables **40** and **42**. Figure 8B shows two connector housings **30** of a same shape mated by a third intermediate housing **30C**. This embodiment allows the use of fiber optic cables having a same connector housing **30** on both ends and therefore provides more flexibility during an installation of a network. These advantages are also provided by the connector housings shown in figure 8C where both connector housings **30** have a same shape, and do not need a third intermediate housing for mating the two connector housings **30**. Figure 8D illustrates a multiple optical connector assembly **200** wherein one connector housing **30** is mated with two connector housings **50** and **52** to split one fiber optic cable **40** retaining a plurality of fibers into two fiber optic cables **42** and **44** each retaining fewer fibers. This is very useful for network applications where many parallel optical fibers are needed, for example, at a central station leading to different locations. Of course, such a connector assembly is useful for splitting a fiber optic cable into any number of fiber optic cables.

[0030] Figure 9A illustrates a transverse section through another embodiment of a multiple connector in accordance with the present invention. Each optical fiber end **22** is supported by a ferrule **5**, and the ferrules **5** are positioned in individual bores **34** within the connector housing **30**, wherein each bore **34** has cross section in the form of a quadratic cross section. A cooperative engagement between the ferrule **5** and the bore **34** is provided. As shown in Figure 9A the ferrule has a flattened face **6** for engaging one of the sidewalls **19** of the bore **34**. A close fit prevents the ferrule **5** from rotating in position. It is evident to those of skill in the art that the term close fit relates to reasonable tolerances and not necessarily to a tight fit. Tolerances are selected based on design requirements and, as such, will vary. As shown, the ferrule **5** may be positioned with the engaging face **6** against any one of the four sidewalls **19**. In another embodiment shown in figure 9B the ferrule **5** comprises etched grooves **62** in a circumferential arrangement. Engaging one of the grooves **62** with a pin **60** in the connector housing bore **34** prevents the ferrule **5** from rotating in position. Figure 9C shows another aligned connector assembly in transverse section. Each of the ferrules **5** has an octagonal surrounding collar **64** to engage matching angular surfaces **66** of the connector housing bores **34**. Optionally, a plurality of optical fibers **22** are retained in one ferrule **5** as illustrated in figure 9D. Further optionally, a plurality of ferrules **5** is retained in one connector housing bore **34** as shown in figure 9E, wherein the ferrules **5** have, for example, a hexagonal cross section.

[0031] A connector housing wherein optical fiber ends are supported by a ferrule **5** is manufactured by iteratively determining the core orientation of each optical fiber end **22** with respect to a reference point of the ferrule 5. When the core orientation is the predetermined core orientation the optical fiber end is affixed in the ferrule **5** such that the core of each of the optical fiber ends is oriented in a predetermined fashion with respect to an indicator element of the ferrule **5**. Indicator elements are, for example, a groove **62** or a flattened face **6**. When the core orientation is other than the predetermined orientation, the core orientation of the optical fiber end **22** is altered. After the optical fiber **22** has been affixed in the ferrule **5**, the ferrule **5** is inserted into a bore **34** of the connector housing **30** such that the key element of the ferrule **5** is disposed in a predetermined relation to a key element **36** of the connector housing **30**. After insertion the ferrule **5** is affixed in the bore **34**.

[0032] In another embodiment a multiple fiber optic connector for connecting a first plurality of optical fiber ends **22** to a second plurality of optical fiber ends **22** is tuned by mating a first connector housing **30A** with a second connector housing **30B** such that key elements **36** are disposed in a predetermined relation one to the other indicating mating of the two connector housings **30A**, **30B** in one and only one orientation. Then, each of the first plurality of optical fiber ends **22** and the corresponding fiber end of the second plurality of optical fiber ends **22** are placed into a first connector housing **30A** and second connector housing **30B**, respectively, such that cores of the first plurality of optical fiber ends **22** and the corresponding core of the second plurality of optical fiber ends **22** have a first orientation relative to each other. Simultaneously light is launched through each of the first and second plurality of optical fibers. The relative orientation of the cores **32** of each fiber pair is adjusted until a preferred coupling is obtained. When a preferred coupling is obtained the orientation of the fiber cores **32** with respect to the key elements **36** is secured by affixing the fibers ends **22** within the connector housings **30A**, **30B**.

[0033] Preferably, each optical fiber end is retained in

a ferrule 5 for support. It is important to provide nearly concentric rotation of the ferrule within the bore so that eccentricities in the position of the fiber core are adjusted without introducing additional change in position from the engaging between the ferrule and the bore. Clearly, some error will occur in manufacture.

[0034] In a further embodiment, a connector according to the invention is formed such that individual fiber alignments within the multiple fiber connector are purposely skewed or offset by individually adjusting particular connectors so as to provide a preferred amount of attenuation between predetermined pairs. Hence, the individual adjustability provides enhanced coupling between individual pairs, or alternatively reduced coupling between particular pairs. Such a connector is highly advantageous in communication networks to equalise the signal intensity in parallel optical fibers after an imbalanced switching device or filtering process.

[0035] The invention disclosed herein provides a tuned multiple optical connector by aligning cores of a plurality of optical fiber ends with respect to a key element of a connector housing retaining said optical fiber ends. Standardisation of the orientation of the cores of the optical fiber ends provides multiple optical connectors for connecting fiber optic cables without significant signal loss or alternatively, with predetermined signal loss. It further allows connection of any fiber optic cables comprising such connectors without adjustment of core orientation during installation.

[0036] A tunable multiple optical connector allowing tuning of individual optical fiber alignments within the multiple optical connector is disclosed. The connector provides a method of individually tuning optical fiber alignment within such a connector for correcting manufacturing irregularities and other imprecision relating to connector construction and use. Of course, numerous other embodiments may be envisaged, without departing from the spirit and scope of the invention.

Claims

1. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising:

    a first connector housing comprising at least a first key element, the connector housing for retaining each of the first plurality of optical fiber ends, a core of each of the first plurality of optical fiber ends oriented with respect to the same first key element in a predetermined fashion in a plane perpendicular to the longitudinal axis of the fiber; and,

    a coupling mechanism for coupling the first connector housing to another connector housing.

2. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 1, comprising:

    a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber ends in a predetermined location and a core of each of the second plurality of optical fiber ends oriented in a plane perpendicular to the longitudinal axis of the fiber in a predetermined fashion with respect to the second key element; and,
    a coupling mechanism for coupling the second connector housing to the first connector housing such that when the second key element and the first key element are disposed in a predetermined relation one to the other; the core of each of the second plurality of optical fiber ends is approximately in alignment with the core of a corresponding optical fiber end of the first plurality of optical fiber ends.

3. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 1, wherein the first key element is a mating key element for substantially limiting coupling of the first connector housing and another second connector housing to a single orientation.

4. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 1, wherein the first connector housing comprises a plurality of bores, each bore for retaining one optical fiber end.

5. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 1, wherein the first connector housing comprises a bore for retaining a plurality of optical fiber ends.

6. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising:

    a first plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule having at least an indicator element such that a core of the optical fiber end is oriented in a plane perpendicular to the longitudinal axis of the fiber, the orientation in a predetermined fashion with respect to an indicator element of the ferrule;

a first connector housing comprising a first key element, the first connector housing for retaining each of the first plurality of optical fiber ends in a predetermined location such that the indicator elements of the ferrules are disposed in a predetermined relation to the first key element of the first connector housing; and,

a coupling mechanism for coupling the first connector housing to another connector housing.

7. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 6, comprising:

a second plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule such that a core of the optical fiber end is oriented in a plane perpendicular to the longitudinal axis of the fiber, the orientation in a predetermined fashion with respect to an indicator element of the ferrule;

a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber ends in a predetermined location such that the indicator elements of the ferrules are disposed in a predetermined relation to the second key element of the connector housing; and,

a coupling mechanism for coupling the second connector housing to the first connector housing such that when the second key element and a first key element of the first connector housing are disposed in a predetermined relation one to the other, the core of each of the second plurality of optical fiber ends is substantially in alignment with the core of a corresponding optical fiber end of the first plurality of optical fiber ends retained in the first connector housing.

8. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 6, wherein the ferrule retains a plurality of optical fiber ends.

9. A tunable multiple fiber optic connector for connecting a first plurality of optical fiber ends retained within a plurality of ferrules to a second plurality of optical fiber ends comprising:

a first connector housing comprising a first key element, the first connector housing for retaining each of the plurality of ferrules in an opening within the first connector housing in one of a plurality of orientations in a plane perpendicular to the longitudinal axis of the opening and prevented from rotating by engaging means; and,

a coupling mechanism for coupling the first connector housing and another connector housing.

10. A tunable multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 9 comprising:

a plurality of ferrules, each ferrule for retaining an optical fiber end having a core wherein the ferrules are physically keyed for insertion into the openings within the first connector housing in each of at least two different orientations.

11. A tunable multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 10, comprising:

a first plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule from the plurality of ferrules;

a second plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule;

a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber ends in a predetermined location such that each ferrule is retained in an opening within the second connector housing in one of a plurality of orientations in a plane perpendicular to the longitudinal axis of the opening and prevented from rotating by engaging means; and,

a coupling mechanism for coupling the second connector housing and the first connector housing such that when the key elements are disposed in a predetermined relation one to the other, the core of each of the second plurality of optical fiber ends is in a predetermined orientation in a plane perpendicular to the longitudinal axis of the bore with respect to the core of a corresponding optical fiber end of the first plurality of optical fiber ends.

12. A method for tuning a multiple fiber optic connector

for connecting a plurality of optical fiber ends comprising the steps of:

iteratively,

determining a core orientation in a plane perpendicular to the longitudinal axis of the core within the fiber, the orientation with respect to a reference point of each optical fiber end of the plurality of optical fiber ends;

when a core orientation is a predetermined orientation in the plane, affixing the optical fiber ends in a connector housing such that the core of each of the optical fiber ends is oriented in the plane in a predetermined fashion with respect to a key element of the connector housing; and,

when the core orientation is other than the predetermined orientation, altering the core orientation of at least one of the plurality of optical fiber ends.

13. A method for tuning a multiple fiber optic connector for connecting a plurality of optical fiber ends comprising the steps of:

determining a core orientation in a plane perpendicular to the longitudinal axis of the core within the fiber, the orientation with respect to a reference point of each optical fiber end of the plurality of optical fiber ends;

when a core orientation is a predetermined orientation, affixing the optical fiber end in a ferrule such that the core of the optical fiber end is oriented in a plane perpendicular to the longitudinal axis of the fiber, the orientation in a predetermined fashion with respect to an indicator element of the ferrule;

when the core orientation is other than the predetermined orientation, altering the core orientation; and,

affixing the ferrules in a connector housing such that the indicator elements of the ferrules are disposed in a predetermined relation to a key element of the connector housing.

14. A method for tuning a multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising the steps of:

affixing each of the first plurality and the second plurality of optical fiber ends in a ferrule;

mating a first connector housing with a second connector housing such that key elements are disposed in a predetermined relation one to the other indicating mating of the two connector housings in one and only one orientation;

placing each of the first plurality of optical fiber ends and the corresponding fiber of the second plurality of optical fiber ends into a first and second connector housing, respectively, such that cores of the first plurality of optical fiber ends and the corresponding core of the second plurality of optical fiber ends have a first orientation relative to each other in a plane perpendicular to the longitudinal axis of the core within the fiber;

simultaneously launching light through each of the first and second plurality of optical fibers;

adjusting the relative orientation of the cores of each fiber pair until a preferred coupling is obtained; and,

when a preferred coupling is obtained securing the orientation of the fiber cores with respect to the key elements by affixing the ferrules within the connector housings.

Fig. 1A
(PRIOR ART)

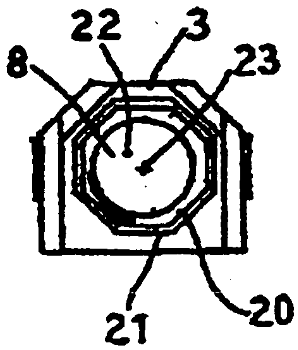


Fig. 1B
(PRIOR ART)

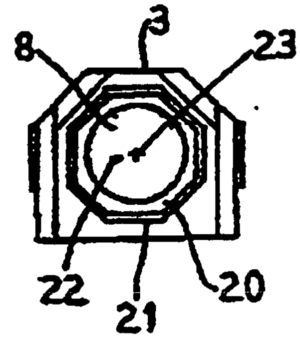
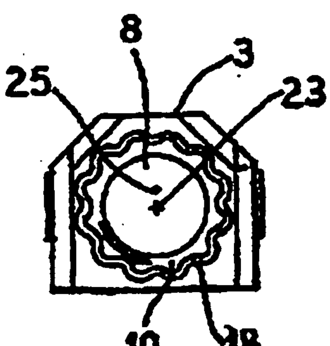
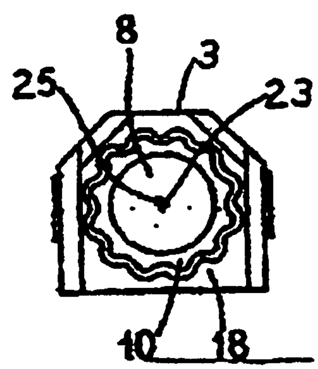


Fig. 2A



PRIOR ART

Fig. 2B



PRIOR ART

Fig. 3

PRIOR ART

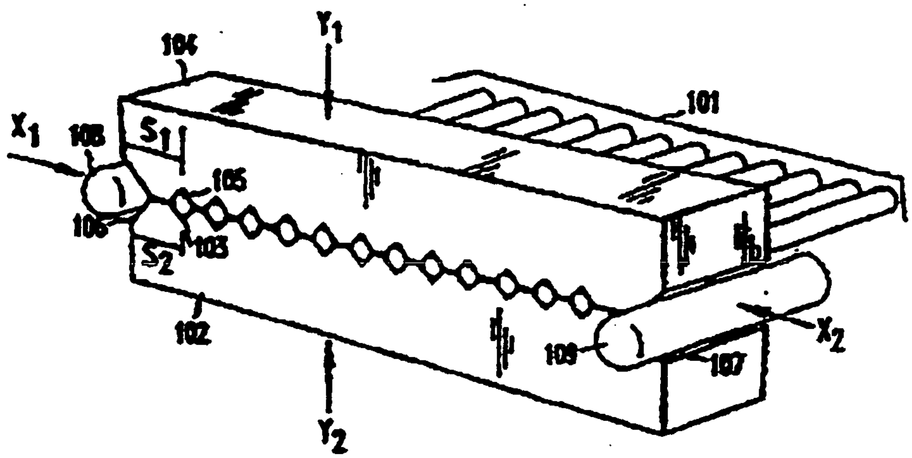
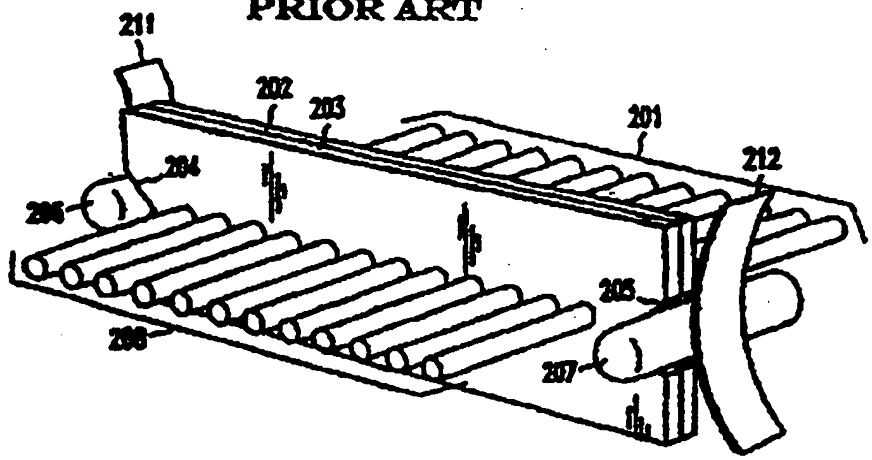


Fig. 4

PRIOR ART



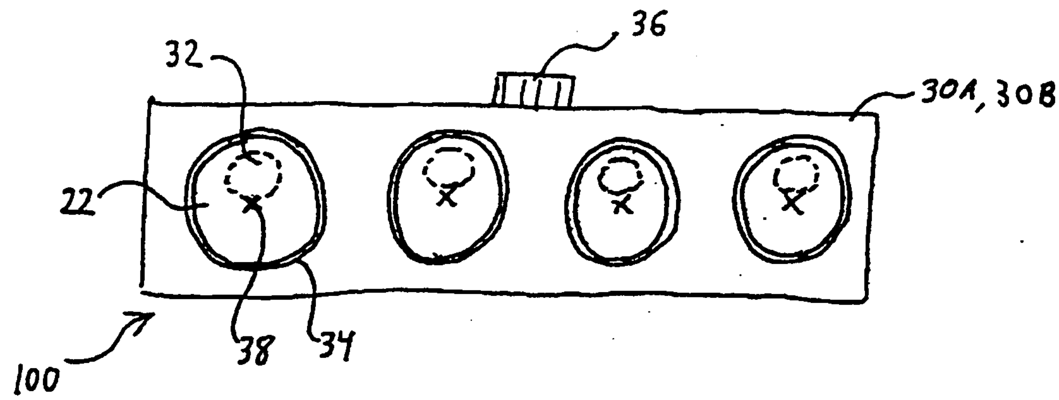


Fig. 5

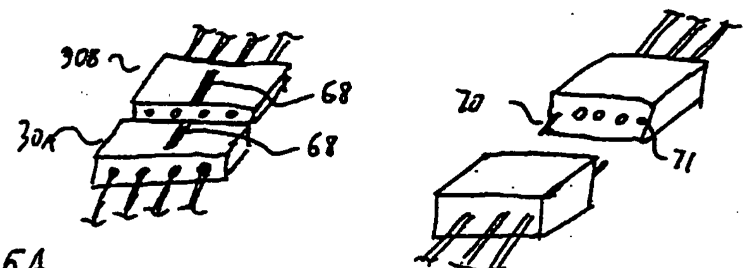


Fig 5A

Fig 5B

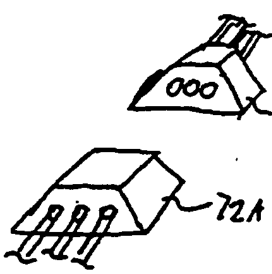


Fig 5C

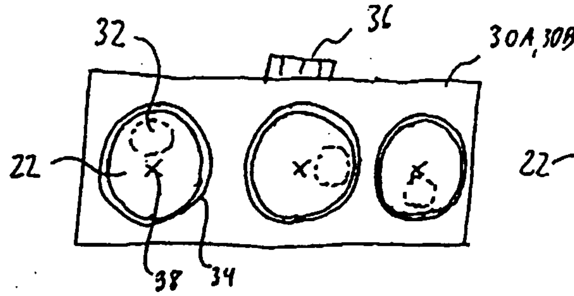


Fig 6A

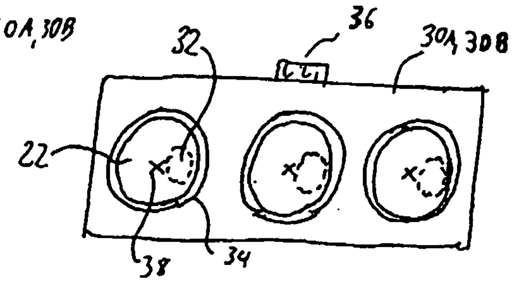


Fig 6B

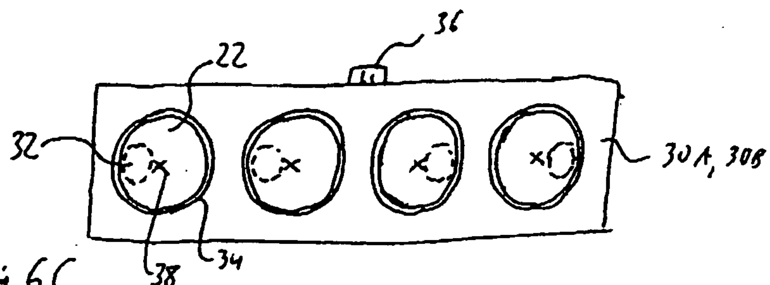


Fig 6C

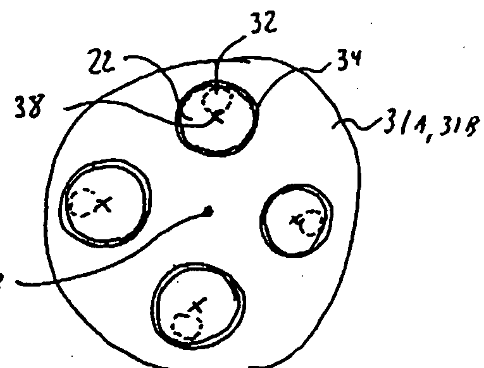


Fig 6D

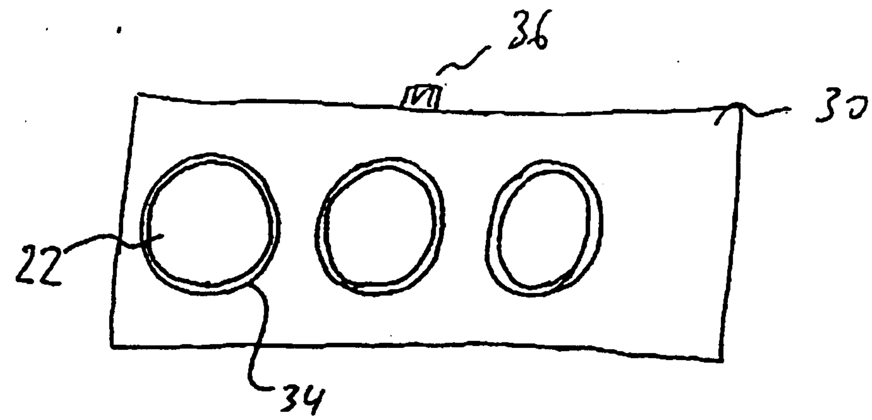


Fig 7A

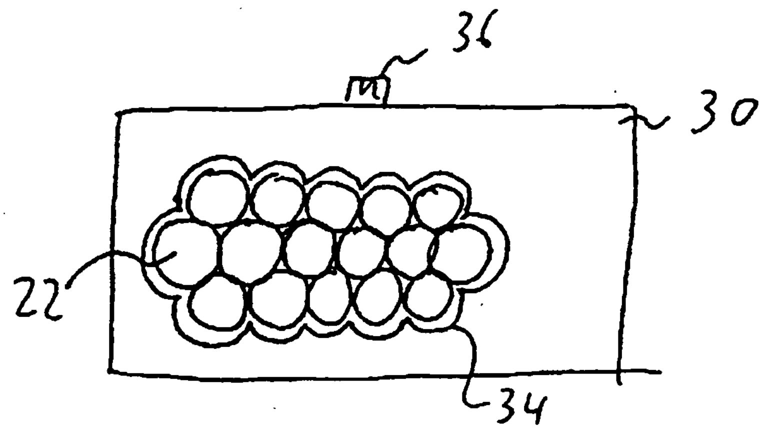


Fig 7B

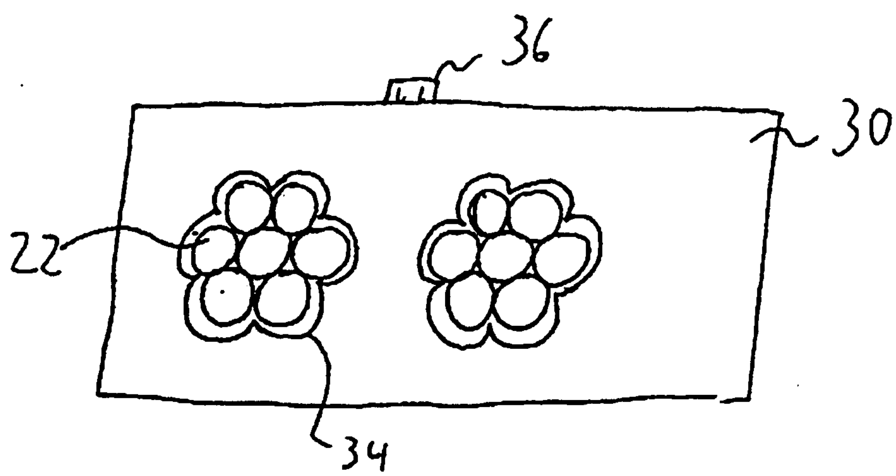


Fig 7C

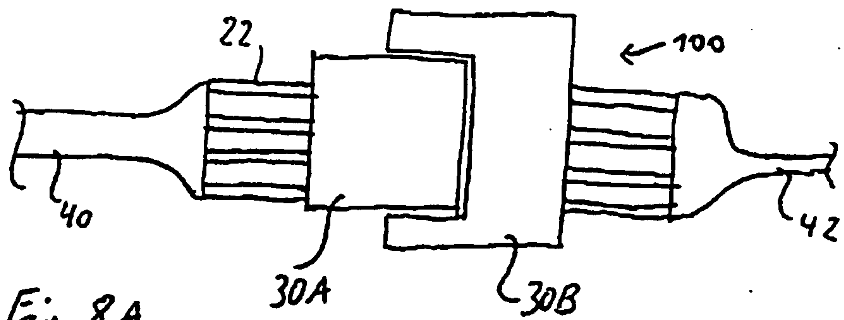


Fig 8A

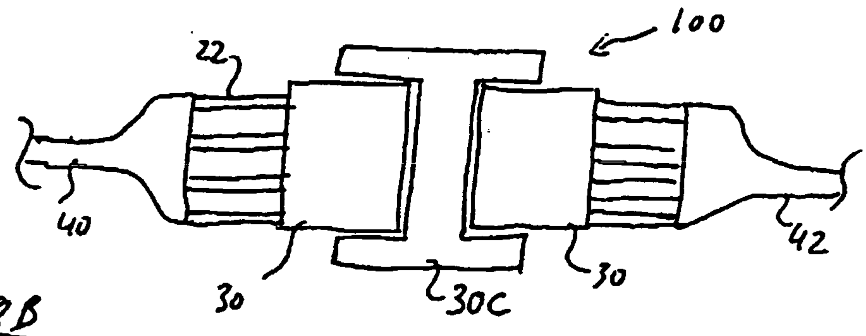


Fig 8B

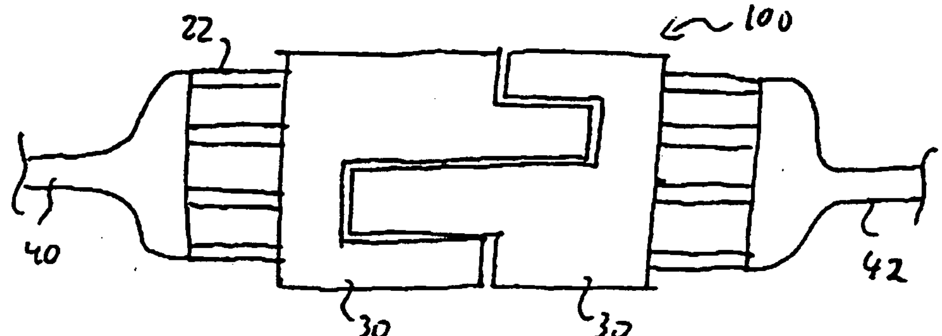


Fig 8C

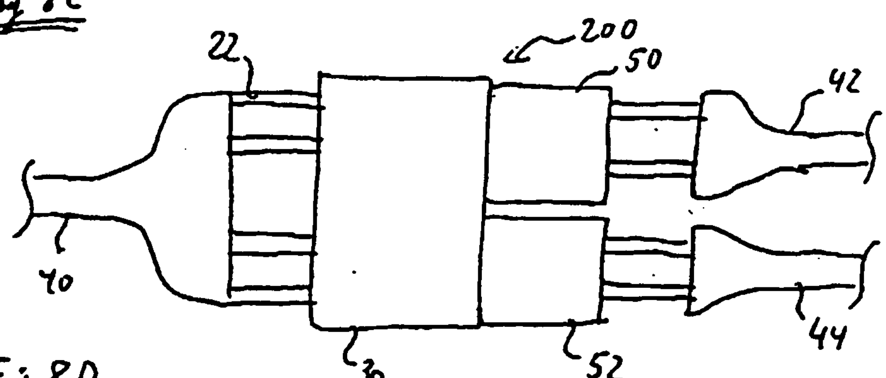


Fig 8D

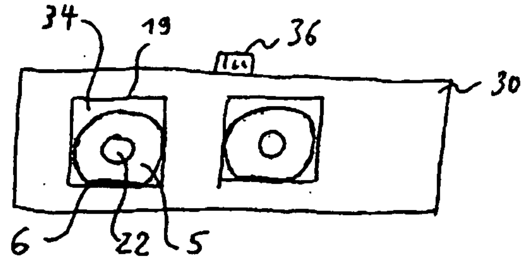


Fig 9A

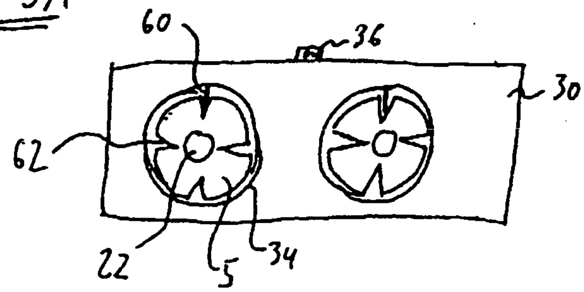


Fig 9B

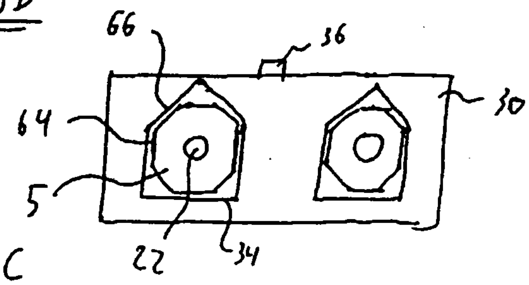


Fig 9C

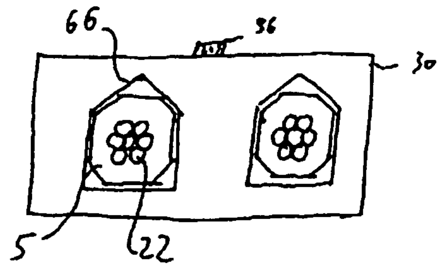


Fig 9D

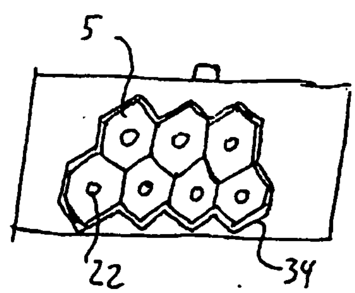


Fig 9E

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 99103428.1

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A	EP 0819960 A2 (SEIKO INSTRUMENTS, INC.) 21 January 1998, abstract, column 9, line 31 - column 12, line 33, column 18, line 46 - column 20, line 13, column 22, line 10 - column 26, line 19, fig. 1, 10,11. --	1,3,4 6,7,9 12-14	
A	EP 0640855 A1 (FUJIKURA LTD.) 01 March 1995, column 4, line 37 - column 7, line 32. --	1,6,9 12-14	TECHNICAL FIELDS SEARCHED (Int. Cl.6)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	31-05-1999	GRONAU

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ON EUROPEAN PATENT APPLICATION NO. EP 99103428.1

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